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FORM PTO-1390 (REV. 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY 'S DOCKET NUMBER 136.162

U.S. APPLICATION NO. (If known, see 37 CFR 1.5 09/890810

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR00/00277	07 February 2000 (07.02.00)	08 February 1999 (08.02.99)

TITLE OF INVENTION AN ON-LINE ATTENUATION DEVICE FOR A MONOMODE FIBRE AND THE ASSOCIATED MANUFACTURING METHOD

APPLICANT(S) FOR DO/EO/US Philippe Chanclou, Monique Thual and Jean Lostec

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [x] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [ ] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [ ] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [ ] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is attached hereto (required only if not communicated by the International Bureau).
   b. [x] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [x] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [x] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [x] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [x] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (unexecuted)
10. [ ] An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [x] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [x] A FIRST preliminary amendment. and substitute specification, claims, abstract.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [x] A substitute specification. claims & abstract.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [x] Other items or information: French-language International Preliminary Examination Report

JC05 Rec'd PCT/PTO 01 AUG 2001

U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
09/890810	PCT/FR00/00277	136.162

21. [x] The following fees are submitted:

		CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... **$1000.00** International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... **$860.00** International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... **$710.00** International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... **$690.00** International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**			
ENTER APPROPRIATE BASIC FEE AMOUNT =		$860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$ --	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	9 -20 =	0	x **$18.00**	$ --	
Independent claims	2 -3 =	0	x **$80.00**	$ --	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$270.00**	$ --	
TOTAL OF ABOVE CALCULATIONS =				$860.00	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. +				$ --	
SUBTOTAL =				$860.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$ --	
TOTAL NATIONAL FEE =				$860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ --	
TOTAL FEES ENCLOSED =				$860.00	
				Amount to be refunded:	$
				charged:	$

a. [x] A check in the amount of $ 860.00 to cover the above fees is enclosed.

b. [x] Please charge my Deposit Account No. 14-1080 in the amount of $ ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [x] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 14-1080 . A duplicate copy of this sheet is enclosed.

d. [ ] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

James E. Nilles
Nilles & Nilles SC
Firstar Center, Suite 2000
777 East Wisconsin Avenue
Milwaukee, WI 53202
Telephone: 414-276-0977
Facsimile: 414-276-0982

James E. Nilles
SIGNATURE

James E. Nilles
NAME

16,663
REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

National Phase of PCT/FR00/00277

International Filing Date: 07 February 2000

Inventors: Philippe Chanclou, Monique Thual, and Jean Lostec

Title: An On-Line Attenuation Device for a Monomode Fibre and the Associated Manufacturing Method

Priority: French Application No. 99 01455; Filed 08 February 1999

Attorney Docket 136.162 Customer No. 023907

PRELIMINARY AMENDMENT

DO/EO/US
Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

This Preliminary Amendment is directed to a new U.S. application as identified above. Please enter this preliminary amendment prior to calculating the fees.

Please substitute the attached specification, claims and abstract (18 pages) for the attached English translation of the PCT application as filed (17 pages), and use the substitute application for examination purposes.

REMARKS

The specification has been amended to insert headings and an Abstract has been added. Claims 3, 5 and 8 has been amended to eliminate the multiple dependencies. A marked-up version of the amended claims is attached and entitled *Version With Markings to Show Changes Made*.

Entry of the amendments and early consideration and allowance are respectfully requested.

Respectfully submitted,

James E. Nilles

James E. Nilles
Registration No. 16,663

Date: August 1, 2001

NILLES & NILLES, S.C.
777 East Wisconsin Avenue, Suite 2000
Milwaukee, WI 53202
Telephone (414) 276-0977
Facsimile (414) 276-0982

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Version With Markings to Show Changes Made

3. An on-line attenuation device according to [one of Claims 1 or 2] claim 1, characterised in that the attenuating element has the same external geometrical parameters as the monomode fibres to which it is connected.

5. An on-line attenuation device according to [any one of the preceding claims] claim 1, characterised in that it comprises a plurality of attenuating elements (A) disposed so as to form a ribbon or a block so as to be placed between ribbons of monomode fibres (R1M, R2M).

8. A method of manufacturing an on-line attenuation device for monomode fibres, according to [one of Claims 6 to 7] claim 6, characterised in that it includes the following steps:

- collectively connecting a ribbon of n monomode fibres with an index gradient (RG) to a ribbon of n silica fibres without a core (RS);
- breaking the ribbon of n silica fibres without a core (RS) so as to obtain n sections (In) of predetermined length (Ls),
- collectively connecting a ribbon of n monomode fibres (R1M) to the n sections of silica without a core (In),
- breaking the ribbon of n multimode fibres with an index gradient (RG) so as to obtain n sections (Gn) of predetermined length (Lg),
- collectively connecting a ribbon of n monomode fibres (R2M) to the n sections with an index gradient (Gn).

AN ON-LINE ATTENUATION DEVICE FOR A MONOMODE FIBRE AND THE ASSOCIATED MANUFACTURING METHOD

BACKGROUND OF THE INVENTION

The invention relates to an on-line attenuation device for a monomode fibre. It also relates to a method of manufacturing such a device.

1. Field of the invention

The field of the invention is that of optical telecommunications and more particularly that of distribution networks.

Distribution networks relate to short-distance links and require significant resources in terms of cost both with regard to the infrastructure and the components. It is in this context that the invention is situated.

It should be stated that there may be a need to use optical attenuators notably in order to obtain an equalisation of the powers of the signal of several communication channels. It is also possible to use such attenuators in order to produce optical interferometers. There may also be a need to use optical attenuators in the laboratory in order to simulate optical transmission lines.

2. Discussion of the Related Art

The fixed on-line attenuators on optical fibres which are used most often are those which use the following techniques:

- transverse offset of two fibres during their welding. This technique is described in the document WO 931 437;

- the use of the curvature of the fibre in order to attenuate the signal. Such a technique is described in the document US 5.581,649;

- thinning of the fibre;

- the use of a section of attenuating doped fibre between two monomode fibres. This technique is described in the document US 5.633.974;

- a section of pure undoped silica without a guide, welded between two monomode fibres. This technique is described in the document US 5.095.519;

- a section of fibre with an index gradient held by a ferrule between two optical fibres. This technique is described in the document JP 62 119503 A.

The technology of attenuators which uses the principle of offset or thinning is not compatible with mass production methods.

The attenuators functioning on the principle of the use of a radius of curvature or a doped section require fairly complex implementation. And the technique of attenuators with a section of undoped fibre does not make it possible to have very broad manufacturing tolerances.

In addition, apart from the complexity introduced with regard to the connection of the fibres by the ferrule, the attenuator with a section of fibre with an index gradient is not suited to a collective production

and does not make it possible to have very broad manufacturing tolerances.

OBJECTS AND SUMMARY OF THE INVENTION

In addition, the introduction of optics as a transmission means in distribution networks makes it necessary to reduce the cost of the components. It is therefore in this context that the inventors have conceived an attenuation function on optical fibre, simple to implement in a reproducible, economical and collective manner (from ribbons of fibres).

The on-line attenuator in accordance with the invention has the advantage of not modifying the external appearance or the geometrical and mechanical parameters of the optical fibre. The value of the attenuation is given with a margin ≤ than that of the commercially available components (plus or minus 0.3 dB).

Thus a first object of the invention relates to an on-line attenuation device for monomode fibres, principally characterised in that it has, placed between two monomode fibres, at least one attenuating element comprising at least one section of multimode fibre with an index gradient and at least one section of silica fibre without a core.

According to another characteristic of the invention, the attenuating element includes at least one other section of silica fibre without a core, the section of fibre with an index gradient being placed between the sections of silica fibres without a core.

According to another characteristic, the attenuating element has the same external geometrical parameters as the monomode fibres to which it is connected. The connection advantageously consists of a weld.

According to another characteristic, the device comprises a plurality of attenuating elements disposed in order to form a ribbon or block so as to be placed between ribbons of monomode fibres.

A second object of the invention relates to a method of manufacturing an on-line attenuation device for monomode fibres, principally characterised in that it consists in successively effecting steps of assembling and breaking ribbons of monomode fibres so as to obtain two ribbons of monomode fibres assembled through an attenuation device which is obtained by breaking at least one ribbon of fibres with an index gradient and connecting to at least one broken ribbon of silica fibres without a core.

According to another characteristic the method includes a step of breaking at least one ribbon of silica fibres without a core and connecting with the broken fibre ribbon with an index gradient thus placed between two ribbons of silica fibre without a core.

According to another characteristic, the method of manufacturing an on-line attenuation device for monomode fibres includes the following steps:

- collectively connecting a ribbon of n monomode fibres with an index gradient to a ribbon of n silica fibres without a core;

- breaking the ribbon of n silica fibres without a core so as to obtain n sections of predetermined length (Ls),

- collectively connecting a ribbon of n monomode fibres to the n sections of silica without a core,

- breaking the ribbon of n multimode fibres with an index gradient so as to obtain n sections of predetermined length (Lg),

- collectively connecting a ribbon of n monomode fibres to the n sections with an index gradient.

The latter step is possibly replaced by the following steps:

- collectively connecting a ribbon of n silica fibres without a core to the n sections with an index gradient,

- breaking the ribbon of n silica fibres without a core so as to obtain n sections of predetermined length (L's),

- collectively connecting a ribbon of n monomode fibres to the n sections of silica without a core.

BRIEF DESCRIPTION OF THE DRAWINGS

Other advantages and particularities of the invention will emerge clearly from a reading of the description which is made below and which is given by way

of illustrative and non-limitative example with regard to the drawings, in which:

- Figure 1a) depicts a particular embodiment of the invention,

- Figures 1b) and 2 depict an attenuator according to respectively a first and a second preferential embodiment of the invention;

- Figure 3 depicts the attenuations in dB as a function of different lengths of the section of fibre with an index gradient in the case of the embodiments depicted in Figures 1a and 1b;

- Figure 4 depicts the attenuations in dB as a function of the different lengths of the section of fibre with an index gradient in the case of the embodiments depicted in Figures 1a) and 2;

- Figures 5a to 5e depict the different steps of a manufacturing method according to the invention;

- Figure 6a depicts schematically the splitting operation;

- Figure 6b depicts the different attenuation levels as a function of the wavelength in the case of a ribbon with four fibres;

- Figure 7 depicts a fibre breaking bench for breaking ribbons according to the method of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The attenuator according to the invention is based on the principle of the mismatching of the light beam coming from one monomode fibre to another monomode fibre.

For the remainder reference can be made to the diagram in Figure 1b), which illustrates an attenuator according to a first preferential embodiment of the invention.

According to this embodiment, a monomode fibre 1n is connected to a monomode fibre 2n through a section of silica without a core In coupled to a section of fibre with an index gradient Gn.

The principle of the attenuator functions on the mismatching of the light beams rather than on the absorption of an intermediate material, such as is the case with fibres attenuating by doping.

The advantage of the use of an undoped section between the monomode fibres (as in the state of the art) and consequently the advantage of the structure proposed by the present invention is that the size and the radius of curvature of the light beam are controlled as required by the choice of the section of fibre with an index gradient.

Figure 2 illustrates a second preferential embodiment according to the invention.

According to this mode, there is a monomode fibre 1n coupled to a monomode fibre 2n through this time on the one hand the section of silica fibre In, the section of fibre with an index gradient Gn and another section of silica fibre Jn.

Adding an additional section of silica Jn between the monomode fibre and the index gradient increases the attenuation range which can be achieved.

It will be understood easily that these embodiments are not the only ones and that it is possible to add as many silica sections and index gradients as is necessary between the monomode fibres according to the attenuation which it is wished to achieve.

The modification of the size and radius of curvature of the Gaussian beam gives rise to coupling losses corresponding to the poor overlap of the two fields. This modification depends on the length of the different sections of silica and index gradient.

In a multimode fibre with index gradient, the light beams undergo a change to their propagation constant along the optical axis. The silica, for its part, is a neutral medium, without interaction, on the propagation. The use of these two media makes it possible to modify the light propagation in order to go from one monomode fibre to another. It is then possible to determine the lengths of these different sections in order to cause a poor overlap of the beam on the monomode fibre according to the attenuation which is required. This is because losses and therefore attenuations are associated with these different overlaps of the beams.

It may be remarked that, even if the component is not symmetrical from the point of view of the lengths and nature of the sections, the attenuation is equivalent in

one direction or other of the propagation in it. It will also be remarked that the sections of fibres depicted in Figures 1b) and 2 have the same external geometrical parameters as the monomode fibres to which they are connected. This characteristic facilitates the use of the attenuator and its manufacturing method, in particular when it is a case of ribbons.

An illustration will now be given of the results which can be obtained from an attenuator according to the invention using curves which can be seen in Figures 3 and 4. First of all, Figure 3 depicts different attenuation curves A1 to A4 corresponding respectively to the variations in attenuation for lengths Lg of sections of fibre with an index gradient varying from 0 to 1,000 micrometres, each of the curves being obtained for a fixed length of silica section Ls. The curve A1 is obtained for a section of silica whose length Ls = 0 micron, that is to say in the absence of a silica section; the attenuator corresponding to this curve A1 is depicted in Figure 1a). The curve A2 is obtained for a section of silica of length Ls = 200 microns, the curve A3, Ls = 400 microns and the curve A4, Ls = 600 microns.

Figure 4 illustrates the case of the different attenuation curves for a double attenuator, that is to say one having two sections of silica, one section on each side of the section of fibre with an index gradient.

Different attenuation curves are also obtained, respectively referenced AA1, AA2, AA3, AA4. The curve AA1

is obtained when the sections of silica Ls are fixed at a zero length, that is to say there is no section of silica; the attenuator corresponding to this curve AA1 is depicted in Figure 1a). The curve AA2 is obtained for variations in the length of the section with an index gradient between 0 and 1,000 micrometres and sections of silica having a length Ls = 200 micrometres. The curve AA3, the section of silica has a length Ls = 400 micrometres and the curve AA4, the sections of silica have a length Ls = 600 micrometres.

The method of manufacturing such attenuators according to the present invention will now be described.

The technology of these attenuators is particularly well adapted to manufacture directly from ribbons of fibres RG, RS as illustrated in Figure 5a.

The simple and reproducible character of these attenuators contributes to a consequent reduction in the cost of the components thus obtained.

The attenuators as depicted in Figures 1a, 1b and 2 can be produced collectively with the method according to the invention which will be described hereinafter.

This method consists in successively effecting steps of connecting and breaking ribbons of fibres so as to obtain two monomode fibre ribbons connected through the attenuation device which is obtained by at least one broken ribbon of fibres with an index gradient.

Hereinafter, the method will be detailed in the case of a production of attenuation devices based on the embodiment depicted in Figure 1b).

Preferentially, in the method according to the invention:

1. - a ribbon RG of n multimode fibres with an index gradient Gn is connected by welding collectively to a ribbon RS of n silica fibres without a core In (Figure 5a);

2. - the ribbon RS of n silica fibres without a core is broken so as to obtain n sections of fibres In of length Ls (Figure 5b);

3. - a ribbon of n monomode fibres R1M is welded to the n sections of silica without a core In (Figure 5c);

4. - the ribbon RG of n multimode fibres Gn with an index gradient is broken so as to obtain n sections of length Lg (Figure 5d);

5. - a ribbon R2M of n monomode fibres is welded collectively to the n sections with an index gradient (Figure 5e).

In the case of an attenuator as depicted in Figure 2a, the method is identical, adding a stage making it possible to have a section of silica Jn between the section with an index gradient Gn and the monomode fibres 2n.

Any attenuation device containing x sections of silica and y sections with an index gradient between two

ribbons of monomode fibres can be obtained collectively according to the method which has just been described.

Figure 6b illustrates experimental results. This figure has experimental attenuation values for a ribbon with four fibres in the windows with a wavelength λ varying between 1.3 and 1.6 micrometres for a length of fibre section with an index gradient Lg = 400 micrometres. These experimental results show that the influence of the wavelength on the attenuation is entirely comparable with the existing attenuation techniques.

The collective manufacturing method which has been described can be implemented using a fibre ribbon breaking bench as depicted in Figure 7.

However, this bench includes a fibre guidance piece for improving the precision of the splitting, depicted in Figure 6a. This is because, in order better to preserve the alignment of the bared fibres at the pitch of 250 µm, it is necessary to guide the end of the fibres in order to limit their opening up. Positioning Vees at a pitch of 250 µm are disposed on the splitter in order to keep the fibres parallel. This guidance piece affords better efficacy to the precision splitting and better evenness of the lengths.

The fibre ribbons can be welded by means of a standard ribbon welder.

The different steps described above are observed by means of a video microscope 200 with annular illumination

placed above the rail 900 supporting the breaking clamp 100.

This is a clamp for breaking the ribbons, for example like the clamp sold by the company Fujikura. Any collective breaking clamp may be suitable in so far as it allows observation of the breaking area from above.

The video microscope 200 is connected to a camera 300 whose image is displayed on a video monitor 500 after processing by a distance measuring system 400. This system projects straight lines which can be moved on the screen and makes it possible, with prior calibration, to measure the distances.

The breaking clamp 100 can move in the three directions x, y and z by means of the unit 600 comprising a manual micrometric movement plate, itself fixed to the rail 900 by means of a slide. The fibre ribbon is moved along the optical axis z by means of the unit 700, which comprises a manual micrometric movement plate connected to the same rail 900 by a slide. This degree of freedom along the optical axis z makes it possible to bring the welding plane to the required position with respect to the blade of the breaking clamp.

The alignment between the welding plane and the outline of the blade is effected visually by means of the video microscope. The movement of the ribbon is adjusted to the required dimension by means of the measuring system 400. The video microscope is held by a bracket 800, the whole being supported by a stable base 1000.

CLAIMS

1. An on-line attenuation device for monomode fibres, characterised in that it has, placed between two monomode fibres (1n, 2n), at least one attenuating element comprising at least one section of multimode fibre with an index gradient (Gn) and at least one section of silica fibre without a core (In).

2. An on-line attenuation device according to Claim 1, characterised in that the attenuation element includes at least one other section of silica fibre without a core (Jn), the section of fibre with an index gradient (Gn) being placed between the sections of silica fibre without a core (In, Jn).

3. An on-line attenuation device according to claim 1, characterised in that the attenuating element has the same external geometrical parameters as the monomode fibres to which it is connected.

4. An on-line attenuation device according to Claim 3, characterised in that the connection consists in a welding of the ends of the fibres opposite each other.

5. An on-line attenuation device according to claim 1, characterised in that it comprises a plurality of

attenuating elements (A) disposed so as to form a ribbon or a block so as to be placed between ribbons of monomode fibres (R_{1M}, R_{2M}).

6. A method of manufacturing an on-line attenuation device for monomode fibres, characterised in that it consists in successively performing steps of connecting and breaking fibre ribbons so as to obtain two ribbons of monomode fibres (R_{1M}, R_{2M}) connected through the attenuation device which is obtained by breaking at least one ribbon of fibres with an index gradient (RG) and connecting to at least one broken ribbon of silica fibres without a core (R_S).

7. A method of manufacturing an on-line attenuation device for monomode fibres according to Claim 6, characterised in that it includes the breaking of another ribbon of silica fibres without a core (R_S) and the connection to the broken ribbon of fibres with an index gradient (RG) thus placed between two ribbons of silica fibre without a core.

8. A method of manufacturing an on-line attenuation device for monomode fibres, according to claim 6, characterised in that it includes the following steps:

- collectively connecting a ribbon of n monomode fibres with an index gradient (RG) to a ribbon of n silica fibres without a core (R_S);

- breaking the ribbon of n silica fibres without a core (R_S) so as to obtain n sections (In) of predetermined length (Ls),

- collectively connecting a ribbon of n monomode fibres (R_{1M}) to the n sections of silica without a core (In),

- breaking the ribbon of n multimode fibres with an index gradient (RG) so as to obtain n sections (Gn) of predetermined length (Lg),

- collectively connecting a ribbon of n monomode fibres (R_{2M}) to the n sections with an index gradient (Gn).

9. A method of manufacturing an on-line attenuation device for monomode fibres, according to Claim 8, characterised in that the last step is replaced by the following steps:

- collectively connecting a ribbon of n silica fibres without a core (R_S) to the n sections with an index gradient (Gn),

- breaking the ribbon of n silica fibres without a core (R_S) so as to obtain n sections (Jn) of predetermined length (L's),

- collectively connecting a ribbon of n monomode fibres (R_{2M}) to the n sections of silica without a core (Jn).

3/PRTS

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PCT as filed

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AN ON-LINE ATTENUATION DEVICE FOR A MONOMODE FIBRE AND THE ASSOCIATED MANUFACTURING METHOD

The invention relates to an on-line attenuation device for a monomode fibre. It also relates to a method of manufacturing such a device.

The field of the invention is that of optical telecommunications and more particularly that of distribution networks.

Distribution networks relate to short-distance links and require significant resources in terms of cost both with regard to the infrastructure and the components. It is in this context that the invention is situated.

It should be stated that there may be a need to use optical attenuators notably in order to obtain an equalisation of the powers of the signal of several communication channels. It is also possible to use such attenuators in order to produce optical interferometers. There may also be a need to use optical attenuators in the laboratory in order to simulate optical transmission lines.

The fixed on-line attenuators on optical fibres which are used most often are those which use the following techniques:

- transverse offset of two fibres during their welding. This technique is described in the document WO 931 437;

- the use of the curvature of the fibre in order to attenuate the signal. Such a technique is described in the document US 5.581,649;

- thinning of the fibre;

- the use of a section of attenuating doped fibre between two monomode fibres. This technique is described in the document US 5.633.974;

- a section of pure undoped silica without a guide, welded between two monomode fibres. This technique is described in the document US 5.095.519;

- a section of fibre with an index gradient held by a ferrule between two optical fibres. This technique is described in the document JP 62 119503 A.

The technology of attenuators which uses the principle of offset or thinning is not compatible with mass production methods.

The attenuators functioning on the principle of the use of a radius of curvature or a doped section require fairly complex implementation. And the technique of attenuators with a section of undoped fibre does not make it possible to have very broad manufacturing tolerances.

In addition, apart from the complexity introduced with regard to the connection of the fibres by the ferrule, the attenuator with a section of fibre with an index gradient is not suited to a collective production and does not make it possible to have very broad manufacturing tolerances.

In addition, the introduction of optics as a transmission means in distribution networks makes it necessary to reduce the cost of the components. It is

therefore in this context that the inventors have conceived an attenuation function on optical fibre, simple to implement in a reproducible, economical and collective manner (from ribbons of fibres).

The on-line attenuator in accordance with the invention has the advantage of not modifying the external appearance or the geometrical and mechanical parameters of the optical fibre. The value of the attenuation is given with a margin ≤ than that of the commercially available components (plus or minus 0.3 dB).

Thus a first object of the invention relates to an on-line attenuation device for monomode fibres, principally characterised in that it has, placed between two monomode fibres, at least one attenuating element comprising at least one section of multimode fibre with an index gradient and at least one section of silica fibre without a core.

According to another characteristic of the invention, the attenuating element includes at least one other section of silica fibre without a core, the section of fibre with an index gradient being placed between the sections of silica fibres without a core.

According to another characteristic, the attenuating element has the same external geometrical parameters as the monomode fibres to which it is connected. The connection advantageously consists of a weld.

According to another characteristic, the device comprises a plurality of attenuating elements disposed

in order to form a ribbon or block so as to be placed between ribbons of monomode fibres.

A second object of the invention relates to a method of manufacturing an on-line attenuation device for monomode fibres, principally characterised in that it consists in successively effecting steps of assembling and breaking ribbons of monomode fibres so as to obtain two ribbons of monomode fibres assembled through an attenuation device which is obtained by breaking at least one ribbon of fibres with an index gradient and connecting to at least one broken ribbon of silica fibres without a core.

According to another characteristic the method includes a step of breaking at least one ribbon of silica fibres without a core and connecting with the broken fibre ribbon with an index gradient thus placed between two ribbons of silica fibre without a core.

According to another characteristic, the method of manufacturing an on-line attenuation device for monomode fibres includes the following steps:

- collectively connecting a ribbon of n monomode fibres with an index gradient to a ribbon of n silica fibres without a core;

- breaking the ribbon of n silica fibres without a core so as to obtain n sections of predetermined length (Ls),

- collectively connecting a ribbon of n monomode fibres to the n sections of silica without a core,

- breaking the ribbon of n multimode fibres with an index gradient so as to obtain n sections of predetermined length (Lg),

- collectively connecting a ribbon of n monomode fibres to the n sections with an index gradient.

The latter step is possibly replaced by the following steps:

- collectively connecting a ribbon of n silica fibres without a core to the n sections with an index gradient,

- breaking the ribbon of n silica fibres without a core so as to obtain n sections of predetermined length (L's),

- collectively connecting a ribbon of n monomode fibres to the n sections of silica without a core.

Other advantages and particularities of the invention will emerge clearly from a reading of the description which is made below and which is given by way of illustrative and non-limitative example with regard to the drawings, in which:

- Figure 1a) depicts a particular embodiment of the invention,

- Figures 1b) and 2 depict an attenuator according to respectively a first and a second preferential embodiment of the invention;

- Figure 3 depicts the attenuations in dB as a function of different lengths of the section of fibre with an index gradient in the case of the embodiments depicted in Figures 1a and 1b;

- Figure 4 depicts the attenuations in dB as a function of the different lengths of the section of fibre with an index gradient in the case of the embodiments depicted in Figures 1a) and 2;

- Figures 5a to 5e depict the different steps of a manufacturing method according to the invention;

- Figure 6a depicts schematically the splitting operation;

- Figure 6b depicts the different attenuation levels as a function of the wavelength in the case of a ribbon with four fibres;

- Figure 7 depicts a fibre breaking bench for breaking ribbons according to the method of the invention.

The attenuator according to the invention is based on the principle of the mismatching of the light beam coming from one monomode fibre to another monomode fibre.

For the remainder reference can be made to the diagram in Figure 1b), which illustrates an attenuator according to a first preferential embodiment of the invention.

According to this embodiment, a monomode fibre 1n is connected to a monomode fibre 2n through a section of silica without a core In coupled to a section of fibre with an index gradient Gn.

The principle of the attenuator functions on the mismatching of the light beams rather than on the absorption of an intermediate material, such as is the case with fibres attenuating by doping.

The advantage of the use of an undoped section between the monomode fibres (as in the state of the art) and consequently the advantage of the structure proposed by the present invention is that the size and the radius of curvature of the light beam are

controlled as required by the choice of the section of fibre with an index gradient.

Figure 2 illustrates a second preferential embodiment according to the invention.

According to this mode, there is a monomode fibre 1n coupled to a monomode fibre 2n through this time on the one hand the section of silica fibre In, the section of fibre with an index gradient Gn and another section of silica fibre Jn.

Adding an additional section of silica Jn between the monomode fibre and the index gradient increases the attenuation range which can be achieved.

It will be understood easily that these embodiments are not the only ones and that it is possible to add as many silica sections and index gradients as is necessary between the monomode fibres according to the attenuation which it is wished to achieve.

The modification of the size and radius of curvature of the Gaussian beam gives rise to coupling losses corresponding to the poor overlap of the two fields. This modification depends on the length of the different sections of silica and index gradient.

In a multimode fibre with index gradient, the light beams undergo a change to their propagation constant along the optical axis. The silica, for its part, is a neutral medium, without interaction, on the propagation. The use of these two media makes it possible to modify the light propagation in order to go from one monomode fibre to another. It is then possible to determine the lengths of these different

sections in order to cause a poor overlap of the beam on the monomode fibre according to the attenuation which is required. This is because losses and therefore attenuations are associated with these different overlaps of the beams.

It may be remarked that, even if the component is not symmetrical from the point of view of the lengths and nature of the sections, the attenuation is equivalent in one direction or other of the propagation in it. It will also be remarked that the sections of fibres depicted in Figures 1b) and 2 have the same external geometrical parameters as the monomode fibres to which they are connected. This characteristic facilitates the use of the attenuator and its manufacturing method, in particular when it is a case of ribbons.

An illustration will now be given of the results which can be obtained from an attenuator according to the invention using curves which can be seen in Figures 3 and 4. First of all, Figure 3 depicts different attenuation curves A1 to A4 corresponding respectively to the variations in attenuation for lengths Lg of sections of fibre with an index gradient varying from 0 to 1,000 micrometres, each of the curves being obtained for a fixed length of silica section Ls. The curve A1 is obtained for a section of silica whose length Ls = 0 micron, that is to say in the absence of a silica section; the attenuator corresponding to this curve A1 is depicted in Figure 1a). The curve A2 is obtained for a section of silica of length Ls = 200 microns, the

curve A3, Ls = 400 microns and the curve A4, Ls = 600 microns.

Figure 4 illustrates the case of the different attenuation curves for a double attenuator, that is to say one having two sections of silica, one section on each side of the section of fibre with an index gradient.

Different attenuation curves are also obtained, respectively referenced AA1, AA2, AA3, AA4. The curve AA1 is obtained when the sections of silica Ls are fixed at a zero length, that is to say there is no section of silica; the attenuator corresponding to this curve AA1 is depicted in Figure 1a). The curve AA2 is obtained for variations in the length of the section with an index gradient between 0 and 1,000 micrometres and sections of silica having a length Ls = 200 micrometres. The curve AA3, the section of silica has a length Ls = 400 micrometres and the curve AA4, the sections of silica have a length Ls = 600 micrometres.

The method of manufacturing such attenuators according to the present invention will now be described.

The technology of these attenuators is particularly well adapted to manufacture directly from ribbons of fibres RG, RS as illustrated in Figure 5a.

The simple and reproducible character of these attenuators contributes to a consequent reduction in the cost of the components thus obtained.

The attenuators as depicted in Figures 1a, 1b and 2 can be produced collectively with the method

according to the invention which will be described hereinafter.

This method consists in successively effecting steps of connecting and breaking ribbons of fibres so as to obtain two monomode fibre ribbons connected through the attenuation device which is obtained by at least one broken ribbon of fibres with an index gradient.

Hereinafter, the method will be detailed in the case of a production of attenuation devices based on the embodiment depicted in Figure 1b).

Preferentially, in the method according to the invention:

1. - a ribbon RG of n multimode fibres with an index gradient Gn is connected by welding collectively to a ribbon RS of n silica fibres without a core In (Figure 5a);

2. - the ribbon RS of n silica fibres without a core is broken so as to obtain n sections of fibres In of length Ls (Figure 5b);

3. - a ribbon of n monomode fibres R1M is welded to the n sections of silica without a core In (Figure 5c);

4. - the ribbon RG of n multimode fibres Gn with an index gradient is broken so as to obtain n sections of length Lg (Figure 5d);

5. - a ribbon R2M of n monomode fibres is welded collectively to the n sections with an index gradient (Figure 5e).

In the case of an attenuator as depicted in Figure 2a, the method is identical, adding a stage

making it possible to have a section of silica Jn between the section with an index gradient Gn and the monomode fibres 2n.

Any attenuation device containing x sections of silica and y sections with an index gradient between two ribbons of monomode fibres can be obtained collectively according to the method which has just been described.

Figure 6b illustrates experimental results. This figure has experimental attenuation values for a ribbon with four fibres in the windows with a wavelength λ varying between 1.3 and 1.6 micrometres for a length of fibre section with an index gradient Lg = 400 micrometres. These experimental results show that the influence of the wavelength on the attenuation is entirely comparable with the existing attenuation techniques.

The collective manufacturing method which has been described can be implemented using a fibre ribbon breaking bench as depicted in Figure 7.

However, this bench includes a fibre guidance piece for improving the precision of the splitting, depicted in Figure 6a. This is because, in order better to preserve the alignment of the bared fibres at the pitch of 250 µm, it is necessary to guide the end of the fibres in order to limit their opening up. Positioning Vees at a pitch of 250 µm are disposed on the splitter in order to keep the fibres parallel. This guidance piece affords better efficacy to the precision splitting and better evenness of the lengths.

The fibre ribbons can be welded by means of a standard ribbon welder.

The different steps described above are observed by means of a video microscope 200 with annular illumination placed above the rail 900 supporting the breaking clamp 100.

This is a clamp for breaking the ribbons, for example like the clamp sold by the company Fujikura. Any collective breaking clamp may be suitable in so far as it allows observation of the breaking area from above.

The video microscope 200 is connected to a camera 300 whose image is displayed on a video monitor 500 after processing by a distance measuring system 400. This system projects straight lines which can be moved on the screen and makes it possible, with prior calibration, to measure the distances.

The breaking clamp 100 can move in the three directions x, y and z by means of the unit 600 comprising a manual micrometric movement plate, itself fixed to the rail 900 by means of a slide. The fibre ribbon is moved along the optical axis z by means of the unit 700, which comprises a manual micrometric movement plate connected to the same rail 900 by a slide. This degree of freedom along the optical axis z makes it possible to bring the welding plane to the required position with respect to the blade of the breaking clamp.

The alignment between the welding plane and the outline of the blade is effected visually by means of the video microscope. The movement of the ribbon is

adjusted to the required dimension by means of the measuring system 400. The video microscope is held by a bracket 800, the whole being supported by a stable base 1000.

CLAIMS

1. An on-line attenuation device for monomode fibres, characterised in that it has, placed between two monomode fibres (1n, 2n), at least one attenuating element comprising at least one section of multimode fibre with an index gradient (Gn) and at least one section of silica fibre without a core (In).

2. An on-line attenuation device according to Claim 1, characterised in that the attenuation element includes at least one other section of silica fibre without a core (Jn), the section of fibre with an index gradient (Gn) being placed between the sections of silica fibre without a core (In, Jn).

3. An on-line attenuation device according to one of Claims 1 or 2, characterised in that the attenuating element has the same external geometrical parameters as the monomode fibres to which it is connected.

4. An on-line attenuation device according to Claim 3, characterised in that the connection consists in a welding of the ends of the fibres opposite each other.

5. An on-line attenuation device according to any one of the preceding claims, characterised in that it comprises a plurality of attenuating elements (A) disposed so as to form a ribbon or a block so as to be placed between ribbons of monomode fibres (R_{1M}, R_{2M}).

6. A method of manufacturing an on-line attenuation device for monomode fibres, characterised in that it consists in successively performing steps of connecting and breaking fibre ribbons so as to obtain two ribbons of monomode fibres (R_{1M}, R_{2M}) connected through the attenuation device which is obtained by breaking at least one ribbon of fibres with an index gradient (RG) and connecting to at least one broken ribbon of silica fibres without a core (R_S).

7. A method of manufacturing an on-line attenuation device for monomode fibres according to Claim 6, characterised in that it includes the breaking of another ribbon of silica fibres without a core (R_S) and the connection to the broken ribbon of fibres with an index gradient (RG) thus placed between two ribbons of silica fibre without a core.

8. A method of manufacturing an on-line attenuation device for monomode fibres, according to one of Claims 6 to 7, characterised in that it includes the following steps:

- collectively connecting a ribbon of n monomode fibres with an index gradient (RG) to a ribbon of n silica fibres without a core (R_S);

- breaking the ribbon of n silica fibres without a core (R_S) so as to obtain n sections (In) of predetermined length (Ls),

- collectively connecting a ribbon of n monomode fibres (R_{1M}) to the n sections of silica without a core (In),

- breaking the ribbon of n multimode fibres with an index gradient (RG) so as to obtain n sections (Gn) of predetermined length (Lg),

- collectively connecting a ribbon of n monomode fibres (R_{2M}) to the n sections with an index gradient (Gn).

9. A method of manufacturing an on-line attenuation device for monomode fibres, according to Claim 8, characterised in that the last step is replaced by the following steps:

- collectively connecting a ribbon of n silica fibres without a core (R_S) to the n sections with an index gradient (Gn),

- breaking the ribbon of n silica fibres without a core (R_S) so as to obtain n sections (Jn) of predetermined length (L's),

- collectively connecting a ribbon of n monomode fibres (R_{2M}) to the n sections of silica without a core (Jn).

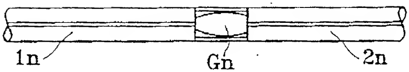

FIG. 1a

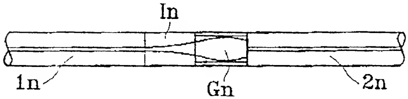

FIG. 1b

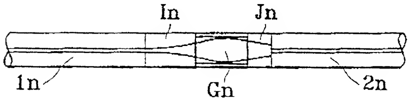

FIG. 2

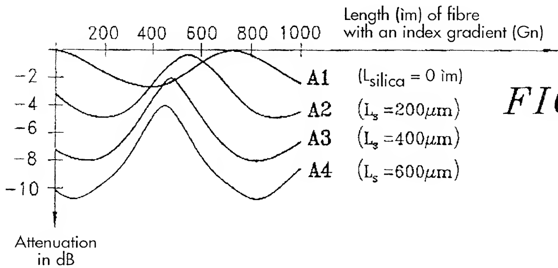

FIG. 3

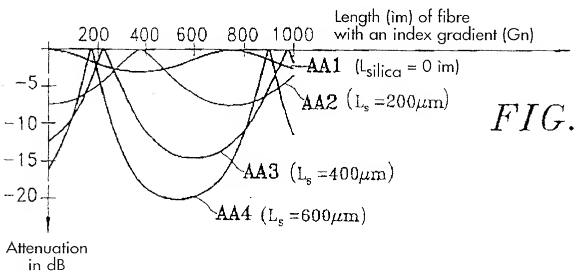

FIG. 4

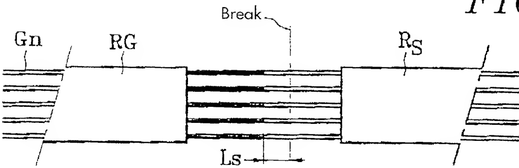

FIG.5a

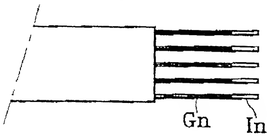

FIG.5b

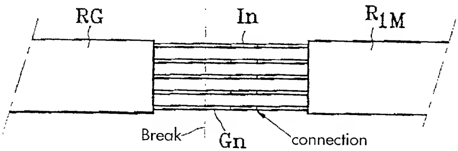

FIG.5c

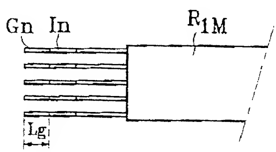

FIG.5d

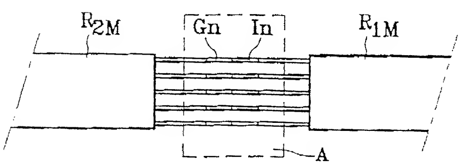

FIG.5e

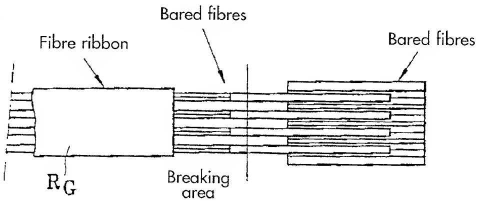

FIG.6a

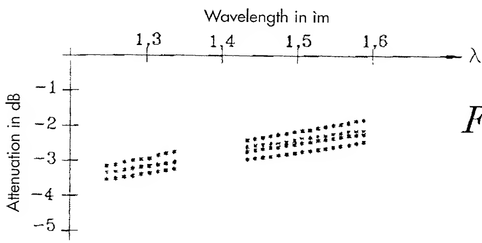

FIG.6b

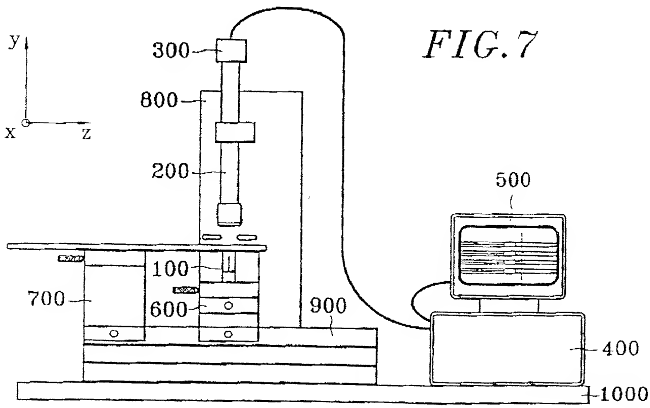

FIG.7

03031

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63) and POWER OF ATTORNEY

☐ Declaration Submitted with Initial Filing
OR
☑ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16(e)) required)

Attorney Docket Number: 136.162
First Named Inventor: Philippe Chanclou et al.
COMPLETE IF KNOWN

Application Number:	09/890,810
Filing Date:	August 2, 2001
Group Art Unit:	Not Known
Examiner Name:	Not Known

As a below named inventor, I hereby declare that:

My residence, mailing address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

An On-Line Attenuation Device for a Monomode Fiber and the Associated Manufacturing Method

the specification of which
- ☐ is attached hereto
  OR
- ☑ was filed on August 2, 2001 and assigned U.S. Serial No. 09/890,810, which is a national phase of PCT International Application Number PCT/FR00/00277, filed on February 7, 2000.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to the patentability as defined in 37 CFR 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)–(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

(Number)	(Country)	(Foreign Filing Date) (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached?
99 01455	France	February 8, 1999	☐	☐ Yes ☑ No
			☐	☐ Yes ☐ No
			☐	☐ Yes ☐ No

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

DECLARATION – Utility or Design Patent Application and POWER OF ATTORNEY

(Application Number)	(Filing Date) (MM/DD/YYYY)	☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.
(Application Number)	(Filing Date) (MM/DD/YYYY)	

As a below-named inventor, I hereby appoint the registered practitioners named below as my/our attorney(s) or agent(s) to prosecute this application, and to transact all business in the Patent and Trademark Office connected therewith:

9

James E. Nilles, Reg. No. 16,663
Andrew J. Nilles, Reg. No. 31,786
Jay G. Durst, Reg. No. 41,723
Lisa M. Gehrke, Reg. No. 38,888
Stephen Michael Patton, Reg. No. 36,235
Thaddeus C. Stankowski, Reg. No. 45,522
Matthew C. Loppnow, Reg. No. 45,314
Lisa A. Brzycki, Reg. No. 40,926
Matthew M. Eslami, Reg. No. 45,488

Direct all telephone calls to James E. Nilles at telephone number (414) 276-0977, facsimile number (414) 276-0982.

Direct all correspondence to: James E. Nilles
NILLES & NILLES, S.C.
Firstar Center, Suite 2000
777 East Wisconsin Avenue
Milwaukee, WI 53202-5345

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of Sole or First Inventor: 1-00 ☐ A petition has been filed for this unsigned inventor

Given Name (first & middle [if any]) and Family Name or Surname: Philippe Chanclou

Inventor's Signature: Philippe CHANCLOU Chanclou Date: 5.10.2001

Residence (city, state, country): Troguery, France FRX Citizenship: French

Mailing Address: Pont Hualec

(city, state, zip, country): F-22450 Troguery, France

Full name of Second Inventor, if any: 2-00 ☐ A petition has been filed for this unsigned inventor

Given Name (first & middle [if any]) and Family Name or Surname: Monique Thual

Inventor's Signature: Monique THUAL MThual Date: 1-10-2001

Residence (city, state, country): Trebeurden, France FRX Citizenship: French

Mailing Address: 5, rue de Liors Eron

(city, state, zip, country): F-22560 Trebeurden, France

Full name of Third Inventor, if any: 3-00 ☐ A petition has been filed for this unsigned inventor

Given Name (first & middle [if any]) and Family Name or Surname: Jean Lostec

Inventor's Signature: Jean LOSTEC Date: 10.10.2001

Residence (city, state, country): Prat, France FRX Citizenship: French

Mailing Address: 14, route de l'Escoben

(city, state, zip, country): F-22140 Prat, France

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